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ABSTRACT

Three experiments, in which subjects read passages of variable readability, measured "cognitive capacity usage" (the attentiocn level to reading material) by recording by subjects reaction times in a seccndary task (responding to a "click"). The data indicated that the easy texts filled cognitive capacity more completely than the difficult texts, while the difficult texts used more "tctal" cognitive capacity (measured by multiplying the reading time for the entire passage by the reaction time to the click) than the easy texts. Arousal patterns, grammatical theory, and various artifacts do not explain these results as adequately as does a cognitive processing model. In that interpretation, the short term memory ("processor") spaces are always full when easy passages are read. Frequent breakdowns occur, however, in the comprehension processes for difficult passages; the short term memory spaces empty temporarily, and these periodic "breakdowns" leave extra capacity available for response to the secondary task. The multiple linear regression model that was based on the experimental data has a coefficient of determination of .75 for predicting cognitive capacity usage with five text characteristics, including comprehensibility, learnability, and the text's "semantic activeness" (word recognition/recall of content words). (RL)

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Reading and Cognitive Capacity Usage: Effects of Text Difficulty

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Running Head: Cognitive Capacity Usage in Text

Reading and Cognitive Capacity Usage:

Effects of Text Difficulty

This paper is concerned with the cognitive demands that written documents place on the reader. The cognitive capacity used in reading text was measured. Since Broadbent (1958) the idea of a limited capacity cognitive processor has been important in cognitive psychology. There is a simple technique for measuring the amount of cognitive capacity used by any cognitive task. In the present experiments this technique has been applied to measure the cognitive capacity used in reading.

The technique is called the secondary task method. The reading task is carried out as usual as the primary task of the reader, and occasionally another, secondary, signal occurs. The more cognitive capacity is being used for the primary task of reading the less is available for the secondary task and the slower is the reaction to the secondary signal. Following Posner (e.g., Posner & Klein, 1973) a click was used as the secondary signal and reaction time to the click was measured. The cognitive capacity demands of the primary task were measured by observing decrements in performance on the secondary task. A simple demonstration of the secondary task technique can be arranged by walking down a long hallway with a colleague and asking him to multiply 37 by 8. Usually he will slow down or stop walking. Here mental multiplication is the primary task, walking is the secondary task, and the amount of slowing down in walking is a rough measure of the capacity demands of the mental multiplication. With an easier multiplication problem, he will slow down less. The secondary task method has been used to measure the cognitive capacity demands of a variety of cognitive tasks (reviewed by Kahnemann, 1973 and Kerr, 1973).

The original hypothesis of the present studies was that cognitive capacity is used in comprehending text. Comprehension involves understanding the mean-

ing of a text. Comprehension is distinguished on the one hand from the perceptual processing routines which recognize letters, and on the other hand from learning the information in the text. Usually these processes occur in a particular order: perceptual processes come first, then comprehension of the meaning, then learning of the material. The passages used in these experiments differed in comprehensibility.

Differences in comprehensibility are easier to recognize than to measure. Some examples of passages which are easy and difficult to comprehend are provided in the method section. The reader is cautioned that a full appreciation of the range of characteristics of the pools of passages used in these studies can only be obtained by examining the full pools of passages (developed by Miller & Coleman, 1967 and Aquino, 1969 for Experiments 1 and 2, and Bormuth, 1971 for Experiment 3). A rough measure of comprehensibility is provided by a cloze test, in which some words are deleted to be put in by the subject. Subjects have never been exposed to the passages before, so this is not a test of learning or memory. Passages which are easy to comprehend typically have short sentences, simple grammar and common words; consequently, it is relatively easy to guess the missing words. Passages which are difficult to comprehend have long sentences, complex grammar and rare words; guessing the missing words is considerably more difficult.

From the original hypothesis of these studies -- that cognitive capacity is used in comprehending text -- it seemed straightforward to deduce that difficult to comprehend passages should use more cognitive capacity than easy to comprehend passages. In the first experiment on this problem, comparisons were made between the cognitive capacity used in reading easy and difficult passages. The finding was counterintuitive: difficult passages apparently used less cognitive capacity than easy passages. That is, reaction time to the click probes was faster while reading difficult passages. The faster reaction time indicated less capacity was used in reading difficult passages. This finding was repeated

in two more experiments.

With this background, the present studies were planned. The first two experiments used the pool of 36 passages provided by Miller and Coleman (1967) and Aquino (1969). The first experiment was a comparison of the cognitive capacity used by the ten easiest and the ten most difficult passages. The second experiment included the remaining 16 passages which were intermediate in difficulty. For each of the 36 passages, previous studies by Miller and Coleman (1967), Aquino (1969) and the present author had made available 10 measures of passage characteristics: five measures of comprehensibility, two measures of recallability, and three measures of semantic features. With these 10 measures, a multiple linear regression model was constructed to predict cognitive capacity usage for each passage. In a third experiment, a different pool of passages varying in difficulty (Bormuth, 1971) was used. The ten easiest and ten most difficult passages were used and the method was the same as in Experiment 1.

The main finding of the early studies — that easy passages used more cognitive capacity than difficult passages -- is counterintuitive to many people. Several alternative explanations have been offered for the finding during the course of these investigations. Data relevant to some of the proposed explanations have been gathered. One alternative explanation is that the interest value of the difficult and easy passages was responsible for the reaction time effects. To investigate this hypothesis, ratings of the interest value of each passage were gathered from college students and correlated with the average reaction time for each passage. Another proposed explanation was that difficult passages were not read, and therefore more capacity could be allocated to the secondary task, leading to faster reaction times for difficult passages. This hypothesis was examined by recording how much time subjects spent reading easy and difficult passages, and by giving a test on the content of the passages to see if they had been read. Data was also gathered to evaluate arousal

and grammatical hypotheses.

During the course of these investigations it has gradually become clear that the term "cognitive capacity usage" can be given either of two quite different meanings. Confusion can be avoided if these are clearly distinguished. The first meaning is the one which has been intended up to this point: cognitive capacity usage is the amount of capacity which is in use at the point in time when the secondary task click probe occurs. The referent for this meaning is the reaction time to the click.

To distinguish it from the first meaning, the second meaning of the term will be called "Total cognitive capacity usage." It refers to the total amount of cognitive capacity used during the entire time a passage is being read. It is calculated by multiplying the average cognitive capacity usage for a passage (reaction time to the click) by the number of seconds taken to read the passage. This measure weights the average capacity usage by the span of time over which that capacity is being used. It reflects the total amount of capacity used in reading the entire passage. A separate analysis for total cognitive capacity usage was conducted post hoc for Experiment 1. Experiment 3 was conducted with a different set of passages to provide an independent test of the effect of passage difficulty on this measure.

EXPERIMENT 1

Method

Subjects. The subjects were 24 students participating as part of a course requirement in an introductory psychology course. They were assigned to the 6 booklets according to a predetermined schedule constructed from a table of random numbers with the restriction that n-1 subjects were assigned to a booklet before the next subject was assigned to it.

Design. Each subject received 10 difficult and 10 easy passages. The design was a mixed hierarchical three factor design with one fixed effect (Difficulty)

and two random effects (Passages, Subjects). This design is treated in detail by Clark (1973, Table 1).

Materials. The materials were 150 word paragraphs ranging in difficulty from easy primary school readers to difficult college textbooks. In the easy passages common words were used in short, grammatically simple sentences. The difficult passages included many rare words, and the sentences were long and grammatically complex. The pool of 36 passages was scaled for comprehensibility by the cloze technique by Miller and Coleman (1967). The ten easiest to comprehend and ten most difficult to comprehend passages, as ranked by Aquino (1969), were chosen for this experiment. The average percentage of words replaced correctly on a cloze test in which every fifth word was deleted was 69% for the easy passages and 35% for the difficult passages. Two examples of easy passages and two of difficult passages are provided below, and Table 2 provides the values for some representative indices of comprehensibility provided by Aquino (1969) and Miller and Coleman (1967).

Insert Table 1 about here

Easy Passages:

A nobleman and a merchant met in a tavern. For their lunch they ordered soup. When it was brought, the nobleman took a spoonful, but the soup was so hot that he burned his mouth and tears came to his eyes. The merchant asked why he was weeping. The nobleman was ashamed to admit he had burned his mouth and answered, "Sir, I once had a brother who committed a great crime, for which he was hanged. I was thinking of his death, and that made me weep." The merchant believed this story and began to eat his soup. He too burned his mouth, so that he had tears in his eyes. The nobleman noticed it and asked the merchant "Sir, why do you weep?" The merchant, who now saw the nobleman

had deceived him, answered "My Lord, I am weeping because you were not hanged together with your brother."

My young friend Jack was counting the contents of his bank -- one, two, three pennies, a nickel, a dime, and a quarter. Over and over he tried, but each time he found forty-three cents, no more. He needed so many things, a baseball, a mitt, and a bat. What should he do? He must earn some money, of course, but how? He thought and thought a long time. Then, taking a pencil and paper, he made a list of all the people who might need the help of a strong, willing boy. There were Farmer Brown, with weeds to be pulled; Mr. Jones, the grocer, with boxes to be carried; Miss White, the milliner, with hats to be delivered; and many others. The next morning he started out merrily with his list. The last time I saw Jack he was playing with a new mitt and bat of his own.

Difficult Passages:

Sometimes great history is made suddenly and dramatically. Sometimes it enters our lives on tiptoe, almost warily. In many instances, men look back later, seeing for the first time the importance of such moments. Thus, few persons were excited when man first split the atom. Probably the first power man learned to control was that of manpower. Then he tamed and trained animals and secured greater power, such as horsepower and elephant power. Next he evolved steam power by burning wood and coal. Then he learned how to get power from dynamite and from burning kerosene and gasoline. When man learned how to split the atom and control its power, he had at his bidding a power far, far greater than any he could harness from burning wood, coal, and gasoline. Finally, atomic fusion, which takes place in the hydrogen bomb, provides

a much greater power than atomic fission provides.

The most recent and the best-controlled of the nerve division experiments is that of Lanier. In three subjects the two main nerves (the lateral and median cutaneous antebrachials) supplying the volar surface of the left forearm were destroyed by injecting their tracts with 95% alcohol. A considerable region corresponding to the peripheral projection areas of the nerves was left anesthetic. These areas, carefully located in advance, were explored systematically for several months before denervation. The same care in mapping was used throughout the 2-year period following the operation. Instrumentation and procedure were such as to guarantee comparability between successive tests, a matter too frequently overlooked in some earlier work. Moreover, quantitative measures of threshold were secured by means of a calibrated mechanical algesiometer (pain), a "limen gauge" (pressure), and a thermoesthesiometer (warmth and cold). All four modalities were found to recover continuously and gradually throughout the process of nerve regeneration.

From reading only these sample passages, reviewers have come to opposed conclusions about the characteristics of this pool of passages. The reader is cautioned that it is necessary to read all 36 passages for a thorough appreciation of the characteristics of the pool of passages.

The 20 passages were arranged in booklets in 6 different random orders with the restriction that each successive set of 4 passages contained 2 easy and 2 difficult passages. In addition to the experimental passages, the booklets contained: a cover sheet, a 3 page passage on marine biology, 6 short answer questions on the marine biology passage, a sheet asking the subject to wait, and 3 filler passages of intermediate difficulty from the Coleman-Aquino pool. Then the

experimental passages appeared, followed by 3 more Coleman-Aquino filler passages.

Procedure. At the beginning of the experiment, the subject was instructed to read the material carefully so that he would be prepared to take a test on it from time to time. Then he was instructed in the use of the reaction time key, and given practice in responding to the clicks. Then the 3 page marine biology passage was read with several click probes, and the 6 short answer questions were answered orally with the experimenter providing feedback and correct answers. During the question-answering period the experimenter calculated the subject's average reading speed for use in placing probes in the next part of the session. Following this, the next 23 pages were read including the first 3 filler passages and the 20 experimental passages. Three passages were included at the end to prevent subjects from knowing the length of the task. They were not read. Reading times were recorded for each page. At the end of the session, about a minute was devoted to instructions and observations for 3 reaction time measurements which were made without reading with foreperiods of 2, 1 and 3 seconds, and then the final test of free recall for passage topics was administered.

Click probe placement. Clicks occurred unexpectedly. For each experimental passage, each subject was programmed to receive 1, 2, or 3 click probes. Post experimental interviews confirmed that this procedure was successful in preventing subjects from anticipating the clicks. The time between clicks was based on the subject's reading speed on the 3 page marine biology text at the beginning of the session. This procedure was successful in approximately equalizing the number of probes each subject received. The reaction times for the probes on each page were averaged.

Results and Discussion

Reaction times. Reaction times were longer while subjects were reading easy passages ($\bar{X}$ = 435 msec) than while they were reading difficult passages ($\bar{X}$ = 399 msec). To determine if this result would generalize across both new sets of passages and new groups of subjects simultaneously, an analysis of

variance like that suggested by Clark (1973, Table 1) was conducted. A quasi-F ratio was used. Passages and Subjects were treated as random factors and difficulty was a fixed factor. The rejection level was $p < .05$. The result was significant, $F'(1,38) = 13.83$, $MSe = 11833$. This analysis shows that this result can be repeated in experiments with randomly selected pools of passages and subjects.

In the secondary task method it is assumed that the longer reaction times for the easy passages indicate that less cognitive capacity was available for reacting to the clicks, presumably because more cognitive capacity was being used for the reading task. Cognitive capacity appears to be more full while easy passages are being read than while difficult passages are being read.

Reading rate and content test. One hypothesis for this result is that readers did not pay attention to the difficult passages. This was investigated by calculating reading rates and by giving a test for content. Reading rates for difficult passages were slower than for easy passages. The average reading rate for the easy passages was 262 words per minute and for the difficult passages it was 182 words per minute. Every subject read the difficult passages at a slower rate than the easy passages. These data are not consistent with the hypothesis that difficult passages were not read. The reading speeds are consistent with average college student reading rates and with those observed by Coke (1974) for easy and difficult passages.

Another way to determine if difficult passages were read is to administer a test for retention of content. It is difficult to find an entirely fair test because usually less is recalled from difficult passages. Any content test is likely to be effected by this to some extent. But the hypothesis that the lower cognitive capacity usage of difficult passages is due to their not being read goes beyond a moderate difference in recall such as would be expected if they were read but not remembered very well. If the difficult passages were not read at all (or only enough to see if they were difficult) there should be a very much

lower level of recall for them than for the easy passages. This admittedly somewhat imprecise prediction was tested by administering a test for recall of the passage topics. After the 20 passages had been read, there was a filled one minute retention interval, and then readers were asked to free recall the topics of as many passages as they could remember. Recall of a passage topic (after a filled retention interval and in the face of retroactive and proactive inhibition) was assumed to indicate that the passage had been read sufficiently to (a) discover the topic and (b) store it in some relatively permanent way. Of the topics recalled, 57% were from easy passages and 43% from difficult passages. It was expected that some difference would be present, because difficult passages are usually remembered less well than easy ones (e.g., Aquino, 1969). The difference was reliable, $t(23) = 3.12$, $\sigma_{est} = 4.49$. The absence of large differences in recall, combined with the data on reading times, indicates that both types of passages were read.

Total cognitive capacity usage. The total cognitive capacity usage was defined as the total amount of cognitive capacity used during the entire period the passage was being read. For each subject, two scores were calculated, one for easy and one for difficult passages. The calculation was made by multiplying the number of seconds taken to read the passages by the average reaction time in milliseconds. For example, the first subject took an average of 29 seconds to read easy passages and his average reaction time for easy passages was 395 ms; his total cognitive capacity usage for easy passages was 29 x .395 = 11.5. The results showed that difficult passages used more total cognitive capacity ($\bar{X} = 19.8$) than easy passages ($\bar{X} = 15.0$). This was true for all subjects (except one tie), $t(23) = 6.31$, $\sigma_{est} = 0.76$. It should be noted that this analysis is not independent of previous ones and was done post hoc. The result should be treated with appropriate caution. This result is quite consistent with commonsense intuitive ideas about difficulty: more

total capacity is used in comprehending passages which are difficult to comprehend.

In summary, it appears that easy passages fill up cognitive capacity more fully during the relatively brief time it is being used. Difficult passages use less capacity at any one time, but use it for longer, thus requiring a greater total amount of capacity during reading. Experiment 2 was conducted to provide cognitive capacity scores for the remaining 16 passages in the pool of 36 passages. With these data, a multiple linear regression model for predicting cognitive capacity was constructed. Also, data relevant to other alternative explanations was gathered.

EXPERIMENT 2

At present, theoretical formulations relating text characteristics to cognitive capacity usage in reading are lacking. A sound foundation for a theory can be built by identifying the characteristics of text which correlate with cognitive capacity usage. A multiple linear regression model was developed with average cognitive capacity usage scores for each of the 36 passages. Ten quantitative indices of various characteristics were available from previous studies. They are summarized in Table 2.

Insert Table 2 here

Method

Reaction time scores for the remaining 16 passages from Aquino (1969) were gathered. The method was the same as in Experiment 1, except that the 16 intermediate passages were used. In both experiments all subjects were exposed to passages at all levels of difficulty and the total length of the session was the same. The ratings of interest, activity, strength and difficulty were gathered by the first author from 20 subjects, each rating all 36 passages on 6-point scales. The extreme values on the dimensions were identified as interesting-dull, active-passive, strong-weak and easy-difficult. The remaining indices were reported by Aquino (1969).

Results and Discussion

Table 2 shows the order of introduction of the variables and the proportion of variance they account for. About 75% of the variance is accounted for by the first five factors, which included measuresof difficulty, recallability, and the semantic feature of activeness. Table 3 shows the simple correlations. The correlation between rated interest and cognitive capacity usage was -.04, providing no support for hypotheses relating cognitive capacity usage and interest.

Insert Table 3 about here

High levels of characteristics of passages which might produce arousal -- strength, activeness and interest -- were not associated with high levels of difficulty, providing no support for the hypothesis that difficult passages were more arousing.

EXPERIMENT 3

The analysis of total cognitive capacity usage was conducted post hoc in Experiment 1. The finding was that difficult passages used more total cognitive capacity than easy ones. This finding was believed to be important for understanding the nature of cognitive capacity usage in reading. Obviously a check was necessary. A new pool of passages varying in difficulty was obtained from Bormuth (1971) and cognitive capacity usage and reading time was determined. Total cognitive capacity usage was calculated and the generality of the finding was tested by treating Passages as a random factor.

Method

The experiment was conducted in the same way as Experiment 1 except that the Bormuth passages were used. They are 250 words long. From the pool of 32,

the 10 easiest and 10 most difficult passages were chosen on the basis of the results of a cloze test provided by Bormuth (1971).

Results and Discussion.

Total cognitive capacity usage. Total capacity usage was greater when difficult passages were read ($\bar{X}$ = 29) than when easy passages were read ($\bar{X}$ = 23). These values were larger in absolute magnitude than those in Experiment 1. This was probably due to the greater length of the passages. The generality of this effect was investigated in an analysis of variance like that conducted in Experiment 1 except that here the dependent measure was total cognitive capacity usage. The result was significant, $F'(1,40) = 17.67$, MSe = 291. This analysis shows that total cognitive capacity usage can be expected to be larger for difficult than easy passages with other randomly selected sets of passages or subjects.

Reaction time. The average reaction time for easy passages ($\bar{X}$ = 374 msec) was greater than that for difficult passages ($\bar{X}$ = 362), $t(23) = 2.29$, σ est = 5.22.

Reading time. For these 250 word passages the average reading time for easy passages ($\bar{X}$ = 61 sec) was shorter than that for difficult passages ($\bar{X}$ = 79 sec). The effect was present for each subject.

General Discussion

There were two basic findings. One was that easy to comprehend passages had longer reaction times on the secondary task than difficult passages. A straightforward interpretation is that cognitive capacity was filled by the reading task more completely when easy passages were being read than when difficult passages were being read. The other finding was that the product of average reaction time and reading time was larger for difficult passages than for easy passages of the same length. A straightforward interpretation is that total cognitive capacity usage was larger for difficult than for easy passages.

Several explanations for these findings will be evaluated and the present state of knowledge about cognitive capacity usage in reading will be summarized.

Explanations based on specific artifacts or lack of generality. The correlation between rated interest of the 36 passages and cognitive capacity usage was -.04, providing no support for hypotheses relating cognitive capacity usage and interest. Difficult passages took longer to read than easy passages, and a recall test for passage topics indicated that topics of both types of passages were recalled. The findings provide no support for the hypothesis that difficult passages had shorter reaction times because subjects paid less attention to them. The basic results generalized statistically, and were replicated with a different pool of passages, indicating that the results are general.

Arousal explanations. Some reviewers have suggested that arousal constructs may be useful in explaining these results. The theme of these explanations is that difficult passages are more arousing than easy ones, and the arousal facilitates responses to the click probe. Two lines of arguement suggest that increased levels of arousal would not facilitate responses to the click probe in such a way that more arousing passages would have faster reaction times. One arguement is that for arousal to have the postulated effect, the level of arousal would have to fluctuate very rapidly from one passage to the next. Each subject read easy and difficult passages in close succession. Passages took about a minute to read. For the level of arousal to facilitate reaction time in difficult passages and not in easy passages, arousal would have to increase rapidly to an effective level during the minute or so the difficult passage was being read, and then decrease very quickly, so the arousal would not persist while an easy passage was being read. The usual conception of arousal is that it is a physiological state which, once induced, takes some time to develop and then subsides over a long period of time. While I have been unable to obtain quantitative estimates of the time periods involved in the arousal process, introspective observations of arousal suggest that it is too sluggish to be a reasonable explanation for the

reaction time results of these experiments.

A second line of arguement (independent of the first) is related to the general effect of arousal on habits of different strengths. The effect of arousal, considered as a form of drive, is to make strong habits stronger and weak habits weaker. In the experiments reported here the two habit systems were reading and responding to the click. Which habit system is strongest? Reading is a habit of long standing, is identified by the instructions as the primary task, and is a continuous task. Responding to the click is a recently acquired habit, is identified by the instructions as the secondary task, and occurs occasionally and unpredictably. Of these two habits, reading is clearly the strongest. Arousal would increase its strength. Responding to the click is the weaker habit. Arousal would decrease its strength. Thus if arousal is an effective factor in these experiments its effect would be to facilitate the reading habit rather than the habit of responding to the click. Passages which induce arousal should therefore have slower reaction times than passages which do not. These two arguements indicate that arousal explanations are not promising candidates for explaining the effects of passage difficulty on reaction time.

A grammatical explanation. Studies of click perception by Bever, Fodor and Garrett (e.g., Bever, 1973; Fodor & Bever, 1965; Garrett, Bever & Fodor, 1966) have a superficial resemblance to the studies reported here. Application of the grammatical theory underlying those experiments to the procedure of the studies reported here yields the prediction that passages with longer clauses should have longer reaction times to the clicks. The length of clauses in easy and difficult passages was examined. The average length of clauses in difficult passages was twice that in easy passages. Thus the grammatical theory predicts that difficult passages should have longer reaction times. Since the opposite result was found, the grammatical theory was not supported.

A cognitive explanation. In difficult passages, it is likely that frequent

breakdowns occur in word recognition and grammatical calculations. When these occur, the short term memory and processing stores are emptied temporarily. This leaves considerable processing capacity available for the secondary task, and fast reaction times are the result. In easy passages, breakdowns do not occur as often, and the processors are usually full of material, leaving less capacity for the secondary task. I am indebted to Professor John Bormuth of the University of Chicago for this interpretation of the reaction time differences between easy and difficult passages (Note 1).

Another way of stating this interpretation is that in reading easy passages, cognitive capacity is fully used all the time. There is little cognitive capacity left over for processing the secondary task, and consequently the reaction to the click probe is relatively slow. But when difficult passages are being read, cognitive capacity is less full of reading material because breakdowns in processing occur often. When the breakdowns occur, cognitive capacity becomes available, and it can be used for processing the secondary task. In reading easy text, capacity is used fully during the relatively brief time it is being used; in reading difficult text, capacity is used less fully but for a longer time.

If this interpretation is correct, it rules out several otherwise plausible ideas about the nature of cognitive processing in reading. One is the idea that literal comprehension processes (word recognition and grammatical calculation) do not require any cognitive capacity because they take place automatically. It is plausible to suppose that some cognitive processes do not use capacity, because it has been established that at least one important cognitive process in reading uses no cognitive capacity. This process is letter encoding (Posner & Boies, 1971; Posner & Klein, 1973). The Posner experiments measured cognitive capacity usage by taking reaction times to click probes, just as in the present experiments. No increase in capacity usage was found by Posner when letters

were encoded, although in the same experiments substantial effects on capacity usage were observed for other cognitive processes. Letter encoding does not use detectable amounts of cognitive capacity. The situation for comprehension processes appears to be quite different: the present experiments show that passages differing in comprehensibility use differing amounts of cognitive capacity. This indicates that comprehension processes use cognitive capacity.

Another plausible idea about the cognitive processing involved in reading is that difficult texts use cognitive capacity fully during the time they are being read. Certainly introspective observations do not differentiate between this view and the opposing view that capacity is less full while reading difficult texts. This study indicates that capacity is not used fully during the reading of difficult passages.

The present state of knowledge about cognitive capacity usage in reading will now be summarized. Letter encoding does not use cognitive capacity. Comprehension processes use cognitive capacity. Difficult to comprehend passages fill capacity less completely than easy passages, because frequent breakdowns occur in comprehending difficult passages, leading to a temporary emptying of the processors. Difficult passages use more total cognitive capacity than easy ones, probably because the frequent breakdowns in processing cause reprocessing.

A third stage of processing in reading is the processing activities associated with learning. I have shown that cognitive capacity usage increase when a text is processed for learning (Britton, Piha, Davis & Wehausen, in press). Cognitive capacity usage was measured during reading in separate groups of subjects with text-relevant inserted adjunct questions, no questions, or irrelevant questions. The typical finding in studies of learning in this situation is that when text-relevant questions begin to appear, more is learned from later sections of the text; the interpretation is that the questions cause subjects to process later sections of the text more thoroughly (Anderson & Biddle, 1975). In Britton

et al, cognitive capacity usage increased markedly for the text-relevant questioned group on sections of text after questions began to appear, but not for the other groups. This finding shows that cognitive capacity is used during the processing which is associated with learning the information in text.

The multiple regression model based on the present Experiments 1 and 2 provides further evidence consistent with the hypothesis that learning from text uses cognitive capacity. The second most important factor in that model was a score reflecting the amount of recall of content words: passages which were difficult to recall used cognitive capacity more fully.

Reference Note

1. Bormuth, J. Personal communication, October 7, 1977.

References

Anderson, R.C. & Biddle, W.B. On asking people questions about what they are reading. In G.Bower (Ed.), Psychology of Learning and Motivation, Vol. 9. New York: Academic Press, 1975.

Aquino, M.R. The validity of the Miller-Coleman readability scale. Reading Research Quarterly, 1969, 4, 342-357.

Bever, T.G. Serial position and response biases do not account for the effect of syntactic structure on the location of brief noises during sentences. Journal of Psycholinguistic Research, 1973, 2, 287-288.

Britton, B.K., Piha, A., Davis, J., & Wehausen, E. Reading and cognitive capacity usage: Adjunct question effects. Memory & Cognition, in press.

Bormuth, J.R. Development of standards of readability: Toward a rational criterion of passage performance. Chicago, Ill: University of Chicago, 1971. (ERIC Document Reproduction Service No. ED 054 233).

Broadbent, D.E. Perception and Communication. New York: Pergamon, 1958.

Clark, H.H. The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 335-359.

Coke, E.V. The effects of readability on oral and silent reading rates. Journal of Educational Psychology, 1974, 66, 406-409.

Fodor, J.A. & Bever, T.G. The psychological reality of linguistic segments. Jouranl of Verbal Learning and Verbal Behavior, 1965, 4, 414-420.

Garrett, M.F., Bever, T.G., & Fodor, J.A. The active use of grammar in speech perception. Perception and Psychophysics, 1966, 1, 30-32.

Kahneman, D. Attention and Effort. Englewood Cliffs, N.J.: Prentice-Hall, 1973.

Kerr, B. Processing demands during mental operations. Memory & Cognition, 1973, 1, 401-412.

Miller, G.R., & Coleman, E.B. A set of thirty-six prose passages calibrated for complexity. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 851-854.

Posner, M.I. & Boies, S.J. Components of attention. Psychological Review, 1971, 78, 391-408.

Posner, M.I. & Klein, R. On the functions of consciousness. In S. Kornblum (Ed.) Attention and Performance IV. New York: Academic Press, 1973.

Table 1

Indices of Comprehension Difficulty Provided by Aquino (1969) and Miller and Coleman (1967)

	Easy		Difficult	
	"A nobleman..."	"My young friend..."	"Sometimes great..."	"The most recent"
Percent correct on cloze[a] test with every 5th word deleted	78.2%	68.3%	43.8%	22.7%
Percent correct on cloze test with 1 word per passage deleted	78.2%	74.0%	51.3%	43.3%
Percent correct on cloze test with each successive word guessed	42.1%	38.6%	30.6%	18.5%

[a]In a cloze test, words are deleted, and the subject's task is to replace them. The measure is the percentage of correct replacements.

Table 2

Order of Introduction of the Factors in the Regression

	R^2
the percentage of correct replacements score on a cloze test with one word deleted from the passage.	.476
number of content words recalled.	.574
the score on a cloze test in which each word was guessed successively.	.673
ratings on the dimension of active-passive.	.729
rankings of difficulty.	.752
the score on a cloze test with every fifth word deleted from the passage.	.775
ratings of difficulty.	.789
ratings on the dimension of interesting-dull.	.795
information gain score.	.799
ratings on the dimension of strong-weak.	.800

Table 3

Correlations of Cognitive Capacity Usage and

10 Passage Characteristics

	Cognitive capacity usage	Cloze test[a] with every 5th word deleted	Cloze test with one word deleted	Cloze test with each word to be replaced successively	Rankings[b] of difficulty	Ratings of[c] difficulty	Content[d] word recall	Information[e] gain score	Ratings of[f] interest	Ratings of[g] activity	Ratings of[h] strength
Cognitive capacity usage	---	.67	.69	.65	-.59	.59	.41	.49	-.04	.34	.08
Cloze test with every 5th word deleted		---	.95	.87	-.94	.90	.85	.62	-.18	.45	.02
Cloze test with one word deleted			---	.87	-.90	.86	.84	.58	-.15	.41	.06
Cloze test with each word to be replaced successively				---	-.90	.78	.85	.33	.08	.18	.31
Rankings of difficulty					---	-.88	-.85	-.53	.08	-.36	-.13
Ratings of difficulty						---	.78	.73	-.28	.57	-.05
Content word recall							---	.42	-.25	.44	-.03
Information gain score								---	-.57	.68	-.42
Ratings of interest									---	-.82	.89
Ratings of activity										---	-.72
Ratings of strength											---

Table 3 (continued)

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[a]Cloze test scores increase in magnitude as the passages become easier to comprehend (from Aquino, 1969).

[b]These rankings increase in magnitude as the passages become more difficult (from Aquino, 1969).

[c]These ratings increase in magnitude as the passages become less difficult.

[d]This score is the mean number of content words an adult recalls after studying the passage for 60 seconds (from Aquino, 1969).

[e]This score is the percentage of additional correct responses the average subject gained as he took for the second time the cloze test in which each word was guessed successively (from Aquino, 1969).

[f]These ratings increase in magnitude as the passage becomes less interesting.

[g]These ratings increase in magnitude as the passage becomes more active.

[h]These ratings increase in magnitude as the passage becomes less strong.

Footnote

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